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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM

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MAINTAINING LAMINAR FLOW IN THE BOUNDARY LAYER USING A SWEPT-BACK WING

By Brennecke

TRANSLATION

"Laminarhaltung der Grenzschichtstromung bei gepfeiltem Flügel"

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SUMMARY

The positions of boundary-layer transition were ascertained experimentally for a swept-back wing and a wing without sweepback which were alike in all other respects and were compared for the same angle of attack ($R_e = 5.6 \times 10^5$). The swept-back wing in a definite range of angle of attack resulted in a backward shift of the transition point on the suction side of the wing. The favorable effect of sweepback on the position of the transition point predicted in reference 1 is confirmed, consequently.

In addition to decreasing the drag at high Mach numbers, the swept-back wing is acknowledged to have additional advantages. (Compare Lippisch reference 1.) These are:

(1) Decrease of the pressure drag. The reduction factor is approximately equal to the cosine of the angle of sweepback.

(2) Backward shift of the transition point.

There are no known experiments which establish experimentally the advantage anticipated. It appeared justifiable, therefore, to carry out some fundamental experiments which might furnish some idea of the magnitude of the advantage expected. Such an experiment is reported in what follows; the advantage of the sweepback appears clearly.

The transition points were ascertained experimentally for a wing without sweepback and one swept back at an angle $\gamma = 35^\circ$, which were alike with respect to surfaces, profile, aspect ratio, and taper. Since this involves a three-dimensional-flow visualization, methods which operate with a pitot survey, which determines the

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transition region by points, are very time consuming in the present case; methods which made the transition point visible throughout, for example, coating and dust precipitation methods, are more suited for the present problem. The dust precipitation method was used (reference 2). This method, recently developed, operates in the following way. Very fine dust (flowers of sulphur was used) is blown from its resting place by an air stream and acquires a large electrical charge in this loosening. If it manages to get into the windstream in this condition, it settles on surfaces traversed by the flow and delivers up its charge. If the surface in the flow is covered with a turbulent boundary layer, many particles get into the vicinity of the surface as a result of the increased diffusion and settle there. Very few particles settle on the surface adjacent to laminar flow. The limit between the laminar and turbulent boundary-layer zones is made visible in this way. The precipitate in the turbulent-flow region is so fine, however, that it is only visible in glancing illumination or view. Figure 1 shows a photograph of the swept-back wing investigated with the limit of dust precipitation on the suction side with $\alpha = 3^{\circ}$ and $R_c = 7.4 \times 10^5$.

The transition point was obtained and drawn up for both wings to be compared by means of this method at various angles of attack and a fixed Reynolds number of 5.6×10^5 (mean chord $l_M = 0.265$ m; wind velocity $v = 30$ m/s) for both the suction and pressure sides. The comparison of the two wings at one angle of attack is made in the following discussion. In this connection, it should be noted that the lift of the two wings is not precisely the same. A previous measurement of forces gave these results: for the trapezoidal wing the value $dc_{aTr}/d\alpha = 3.78$, for the swept-back wing $dc_{aPf}/d\alpha = 3.5$.

The transition point follows a nearly straight-line course over the half of the wing in each case investigated.[1] The regions of laminar or turbulent flow consequently have trapezoidal form on each half of the wing and the portions of the entire wing surface that relate to these regions are determined by the position of the transition point at the center section of the wing semispan.

The results of the investigation are shown in figure 2. At $\alpha = 0^{\circ}$ there is no distinct difference with regard to the position of transition on the upper and lower surfaces of the two wings. At $\alpha = 3^{\circ}$ transition occurs much farther back on the

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[1]This straight-line demarcation in many cases did not run at the same proportion from the leading edge of the wing, relative to the actual chord of the wing, but somewhat inclined to it. No systematic change in this slope, however, was perceptible.

swept-back wing than on the unswept wing although this superiority decreases at greater angles of attack. Figure 2 shows that for $\alpha = 3^\circ$ the surface of the suction side of the swept-back wing has approximately 0.31 more laminar flow than the corresponding side of the wing without sweepback. Possibly 0.04 of the pressure side of the swept-back wing, on the other hand, has additional turbulent flow beyond that over the pressure side of the wing without sweepback. This shift of transition as a result of sweepback leads to the following drag saving at $\alpha = 3^\circ$, if the estimated value of $\Delta c_f = 0.0035$ is taken as a basis for the difference of the friction coefficients Δc_f between turbulent and laminar friction, which taken rigorously holds only for a flat plate and one position of the transition point at $R_e{*} = 0.5 \times 10^6$.

$$\Delta c_w = \left(\frac{\Delta F_{\text{Suction side}}}{F_{\text{Wing}}} - \frac{\Delta F_{\text{Pressure side}}}{F_{\text{Wing}}}\right)\Delta c_f$$

$$= (0.27)(0.0035)$$

$$= 0.00095$$

With an estimated drag coefficient of $c_w = 0.008$ for the wing without sweepback, as a result of sweepback there is an improvement of:

$$\frac{\Delta c_w}{c_w} \sim \frac{0.00095}{0.008} = 12 \text{ percent}$$

To find a physical explanation for the favorable behavior of the boundary layer on the swept-back wing relative to the transition point is still premature because the present state of knowledge for the simple case of the two-dimensional boundary layer at the transition from laminar to the turbulent condition must be advanced. The predictions made in reference 1 regarding the favorable boundary-layer transition behavior of the swept-back wing are based on the concept that the lateral "suction" of the boundary layer at the wing center section is the cause of the backward shift of the transition point. Accordingly, the largest backward shift would be expected at the wing center and only a slight backward shift, or even a forward shift of the transition point, would be expected at the wing tip.

The experiments failed to disclose such behavior; only the fact remains that the lateral travel of the boundary layer on a swept-back wing has a beneficial effect on the position of the transition point on the suction side. The question of whether this beneficial behavior is maintained at higher R_e numbers and higher Mach numbers, and whether a further improvement is possible through the application of laminar-flow profiles remains open and will be the subject of further investigations, if necessary.

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REFERENCES

1. Bericht über die Sitzung "Nurflügelflugzeuge." Bericht 164/Vorbericht, Lilienthalgesellschaft für Luftfahrtforschung. Diskussionsbemerkung Lippisch, p. 50.

2. Brennecke: Verfahren zur Sichtbarmachung des Umschlagpunktes der Grenzschicht. Technische Berichte Bd. 10 (1943)Nr. 6., pp. 179-180.

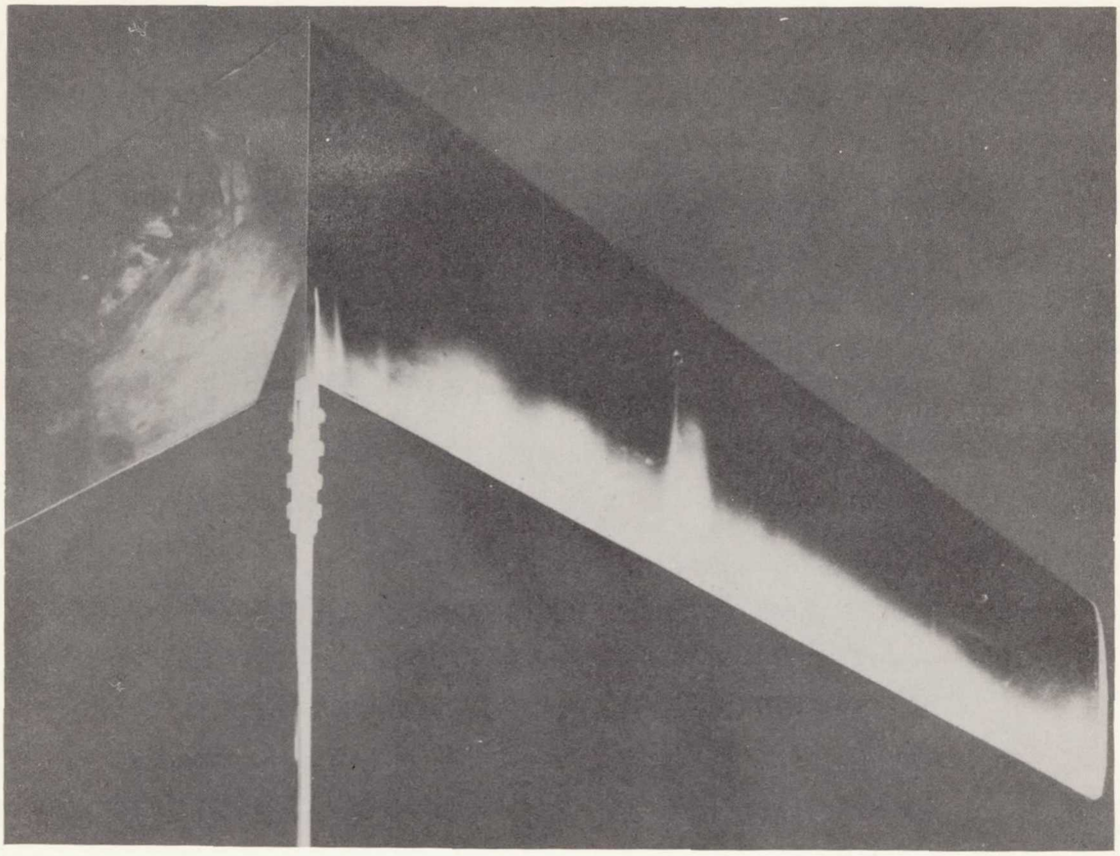

Figure 1.- The transition point made visible on a swept-back wing by the dust precipitation method. $\alpha = 3^{o}$; $R_e = 7.4 \times 10^{5}$.

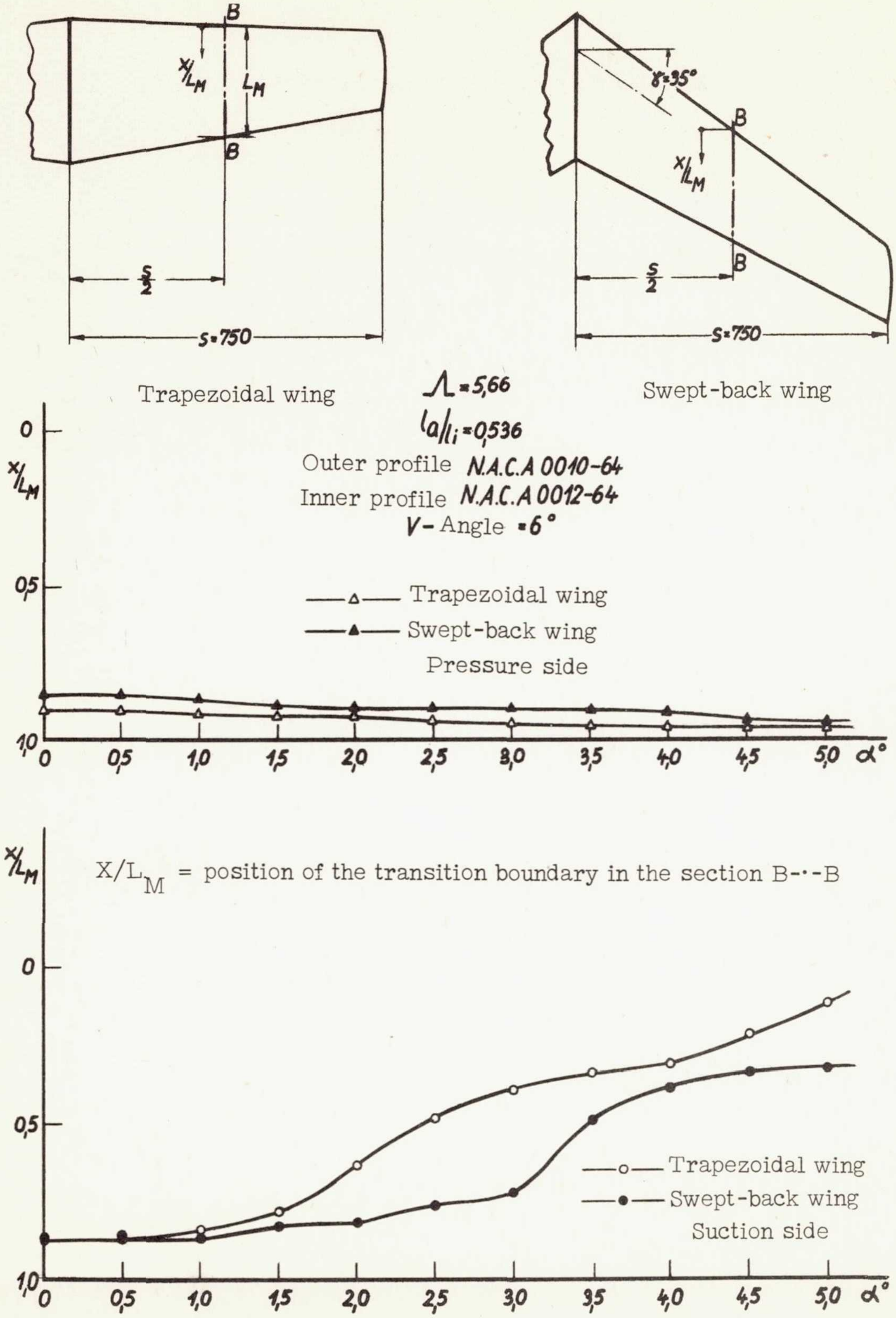

Figure 2.- Position of the transition point in the center section of half a wing as a function of the angle of attack for a swept-back wing and one without sweepback.